Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: TERRANOVA: Terahertz Wireless Access Technologies – System and Hardware Architecture Options

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Re: none

Abstract: The presentation introduces the planned activities in the European Union funded research project TERRANOVA. It discusses at an early project stage the considered hardware options and the envisioned system applications.

Purpose: To give an overview about the planned activities in the project TERRANOVA and to enable potential collaborations.

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Outline

- Overview TERRANOVA
- Hardware Options
  - Optical Transponder
  - DSP Testplatform
  - THz Frontend
- System Architectures
  - Point-to-point
  - Point-to-Multipoint
  - Indoor quasi-omnidirectional
TERRANOVA consortium

Fraunhofer

JCP C

PICadvanced

altice labs

UNIVERSITY OF OULU

INTRACOM

TELECOM

Project duration: July 2017 - December 2019
Vision for Systems Beyond 5G

Systems Beyond 5G - expectations:

- Unprecedented performance excellence, in the Tbps regime
- Inherently support a large dynamic range of novel usage scenarios that combine extreme data rates with agility, reliability, zero response time and AI
- Cost-efficient and flexible provision of high-speed data connections guaranteed, zeroing the ‘digital divide’

Vision:

- Extend the fibre optic systems QoE and performance reliability to wireless, by exploiting frequencies above 275GHz for access and backhaul links
THz Opportunity

- THz wireless bandwidth fits to optical bandwidth / bitrate in current transponder solutions (20..30 GHz/100..200 Gbit/s)
- Challenges: THz-optical interface, high fractional bandwidth (15..25%)
THz unique Challenges

- Bridge the THz ‘gap’
- Tackle the THz propagation characteristics
  - Ultra wideband and extremely directional wireless links
  - Absorption Loss
  - Attenuation with distance
- Devise a new network information theoretic framework imposed by the new disruptive characteristics of the channel
- Design MAC protocols tailored to ‘pencil-beam’ access, coordinate MAC and caching strategies
TERRANOVA System Concept

Key performance indicators:
- Tb/s
- Range
- Zero latency

Fundamental characteristics:
- THz band attenuation
- Information theoretic framework

Enablers:
- Pencil-beam antenna
- Modulation
- Caching

Key technology modules:
- THz frontend
- Phase shifting
- Fiber optic & THz wireless

Usage scenarios:
- THz wireless backhaul
- THz wireless access for cyber-physical systems
- THz wireless local access
TERRANOVA Vision and Objectives

- **Vision**
  - Bring “Tbit/s Speeds Out of the Fiber”
  - Co-design of Optical and THz Wireless
  - Co-design Of Signals, Codes & Protocols

- **Pillars**
  - Tbit/s Wireless Connectivity
  - THz Wireless Access & Backhaul Networks
  - E2E Optimised THz System Architecture

- **Objectives**
  - THz-frontend
  - Frontend to antenna interface
  - Silicon baseband DSP
  - THz beamforming arrays
  - THz baseband unit
  - THz channel & propagation models
  - Pencil-beam based interference model
  - Network information theoretic framework
  - Hybrid MAC protocols
  - Devices discovery
  - Caching overlay
  - Adaptable resource management framework

- **Actions**
  - Tbit/s wireless access
  - THz wireless’ link
  - E2E ‘zero’ latency
  - Range of fiber optic – THz wireless’ link
  - Reliable connectivity of infinite modes

- **Main KPIs**
  - Baseband DSP for fiber optic – THz wireless’ link
  - Optical RF-frontend (optical to THz interface)
  - E2E optimised resource management for THz backhaul and access
System Overview

[Diagram showing optical transceiver and HF-frontend system overview]
Optical Transponder

Coherent Module Segmentation

<table>
<thead>
<tr>
<th>DSP on Line Card</th>
<th>Fixed</th>
<th>Pluggable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete</td>
<td></td>
<td>ACO</td>
</tr>
<tr>
<td>DSP in Module</td>
<td>Transponder</td>
<td>DCO</td>
</tr>
</tbody>
</table>

- Support up to 100/200 Gbit/s, single wavelength (32 GBAud DP-QPSK/16QAM)
- Next generation 400/600 Gbit/s, single wavelength (64 Gbaud DP-16QAM/64QAM)

ACO = Analog Coherent Optics
DCO = Digital Coherent Optics
## Optical Transponder

### State-of-the-art Modules

<table>
<thead>
<tr>
<th>Aspect</th>
<th>OIF 4”x5”</th>
<th>CFP</th>
<th>CFP2</th>
<th>CFP4</th>
<th>QSFP28</th>
</tr>
</thead>
<tbody>
<tr>
<td>W x L x H, mm³</td>
<td>101.6 x 127 x 25.4</td>
<td>82 x 145 x 14</td>
<td>41.5 x 106 x 12.4</td>
<td>21.5 x 92 x 9.5</td>
<td>18.4 x 72 x 8.5</td>
</tr>
<tr>
<td>Power class</td>
<td>45W</td>
<td>8W</td>
<td>3W</td>
<td>1.5W</td>
<td>1.5W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16W</td>
<td>9W</td>
<td>3W</td>
<td>2.0W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24W</td>
<td>12W</td>
<td>6W</td>
<td>3.5W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32W</td>
<td>15W</td>
<td>7.5W</td>
<td>4.0W</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18W</td>
<td>9W</td>
<td>4.5W</td>
</tr>
<tr>
<td>Electrical interface</td>
<td>168 pins</td>
<td>148 pins 10x10G / 4x25G</td>
<td>104 pins 10x10G / 4x25G / 8x25G</td>
<td>56 pins 10x10G / 4x25G</td>
<td>38 pins 4x25G</td>
</tr>
</tbody>
</table>

### Telecom application

- C-band DCO
  - 100G-400G Single/Dual-carrier for metro, long-haul and subsea

### Datacom application

- 100G CWDM4 (2km) 100G LR4 (10km) and ER4 (40km)
DSP Testplatform

- Hardware-platform for real-time testing of digital signal processing algorithms
- Emulation of a THz baseband unit

<table>
<thead>
<tr>
<th></th>
<th>DSPP 124x plug-in board</th>
<th>DSPP 144x plug-in board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of board</td>
<td>Analog-to-Digital Converter</td>
<td>FPGA processor</td>
</tr>
<tr>
<td>Number of channels per board</td>
<td>up to 2</td>
<td>-</td>
</tr>
<tr>
<td>Sampling rate per channel</td>
<td>56 GSa/s</td>
<td>-</td>
</tr>
<tr>
<td>Nominal resolution</td>
<td>8 bit</td>
<td>-</td>
</tr>
<tr>
<td>Analog 3dB-bandwidth</td>
<td>15 GHz</td>
<td>-</td>
</tr>
<tr>
<td>Internal FPGAs</td>
<td>Virtex Ultrascale (XCVU190)</td>
<td>Virtex Ultrascale Plus (XCVU13P)**</td>
</tr>
<tr>
<td>Total* available CLB LUTs</td>
<td>1,074,240</td>
<td>1,728,000**</td>
</tr>
<tr>
<td>Total* available CLB Flip-flops</td>
<td>2,148,480</td>
<td>3,456,000**</td>
</tr>
<tr>
<td>Total* available Block RAMs (36 Kb each)</td>
<td>3,780</td>
<td>2,625 + 10,000 UltraRAM**</td>
</tr>
<tr>
<td>Total* available DSP slices</td>
<td>1,800</td>
<td>12,288**</td>
</tr>
<tr>
<td>Interface speed</td>
<td>up to 560 Gb/s (backplane)</td>
<td>up to 560 Gb/s (backplane)</td>
</tr>
</tbody>
</table>
THz Frontend

Fraunhofer IAF THz Frontend

<table>
<thead>
<tr>
<th></th>
<th>FhG-IAF</th>
<th>Analog Devices HMC6300/6301</th>
<th>Infineon BGT80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Band (GHz)</td>
<td>275 - 325</td>
<td>57 - 64</td>
<td>71 – 76, 81 - 86</td>
</tr>
<tr>
<td>RF signal bandwidth (GHz)</td>
<td>50</td>
<td>up to 1.8</td>
<td>0.05 - 1</td>
</tr>
<tr>
<td>Psat (dBm)</td>
<td>0 dBm</td>
<td>17 dBm</td>
<td>21 dBm</td>
</tr>
</tbody>
</table>

- 1st generation THz frontend prototypes
- THz generation by direct conversion

State-of-the-art reference
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Application Scenarios

Point-to-Point

Point-to-Multi-Point

Indoor quasi-omnidirectional
Point-to-Point

- Transparent optical link: Photonic Radio
- Challenge: Optical DSP used for wireless channel impairment mitigation
Point-to-Multipoint

- Uplink: multiple access
- Downlink: space- and time-division multiple access
- LoS, symmetric full duplex (per time slot)
- Challenge: Dynamic beam steering over large angles with pencil beams

up to 500 Gbit/s
Indoor

- Uplink: non-THz technologies
- Downlink:
  - Broadcast of multiple beams with identical data
- NLoS, half duplex
- Challenge: Multi-path fading at THz frequencies
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Thank You !